

# RESEARCH MEMORANDUM

MODEL FLIGHT INVESTIGATION OF A NONLIFTING  
WINGED TOW TARGET

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NATIONAL ADVISORY COMMITTEE  
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## WINGED TOW TARGET

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## SUMMARY

An experimental investigation was conducted in the Langley free-flight tunnel to study the dynamic stability characteristics at low speeds of a winged tow-target model, the wings of which were free to float about a spanwise axis. The purpose of hinging the wings for a high-speed tow target was to reduce the possibility of lateral divergences at high speeds caused by out-of-trim rolling moments arising from small differences in incidence between the wing panels. The model was tested with unswept wings for two chordwise hinge locations and with a  $45^\circ$  sweptback wing for one hinge location.

When the wing panels were hinged to float independently of each other, the motions of the model were generally characterized by an unstable rolling and yawing oscillation in which the wing panels moved differentially so that the motion appeared to resemble an aileron-free oscillation. The stability of the model was more satisfactory when the wing panels were hinged to move together rather than independently. In either of the cases with the wing panels hinged, moving the aerodynamic center of the wing rearward with respect to the hinge improved the stability of the model and it was possible to obtain stability at speeds up to the maximum speed available for the tests. This speed represented 165 miles per hour for a full-scale target. This result does not insure that satisfactory stability can be obtained at greater speeds; in fact, the test results indicate that stability might be difficult to obtain at high speeds, particularly with the wing panels hinged independently.

## INTRODUCTION

Recent tests of some high-speed winged tow targets have revealed divergences at high speeds. These divergences have been found to result from out-of-trim rolling moments caused by very small differences in incidence between the two wing panels. Because it is impractical to

assemble the targets under service conditions to the tolerances required to reduce the out-of-trim moments to acceptable values, it has been proposed that the wing panels be free to pivot in incidence in order to reduce the unsymmetrical moments resulting from differences in incidence between the wing panels, aeroelastic deformation of the wings, or damage to the wings from gunfire. At high speeds the drag of the target is high relative to its weight, so that with the wings producing no lift such a tow target would trail slightly below the towing airplane. With the target in this position the towline produces static restoring forces.

In order to determine the dynamic stability characteristics of tow targets having free-floating wings of this type, tests have been made in the Langley free-flight tunnel on a general research tow-target model with both unswept and sweptback wings being used. The effect of mass balance of the wing and the effect of varying the chordwise position of the hinge for the straight wings were investigated. In addition to tests with the wings floating freely, the model was tested with the wings fixed rigidly to the body to provide a basis for evaluating the stability of the nonlifting tow-target models relative to that of conventional tow-target models.

#### APPARATUS AND TESTS

The model used in the tests was a general research design, which did not represent any existing target. The same fuselage and tail surfaces were used in all tests but the wing configuration was changed. Figures 1 and 2 show sketches of the model in the five test configurations. Configurations 1(a), 2(a), and 3(a) are shown in solid lines. Configurations 1(b) and 2(b) consisted of configurations 1(a) and 2(a), respectively, with the aerodynamic unbalancing surfaces shown in dashed lines attached to the wings. The weight and geometric characteristics of the models are given in table I. The shaft to which the wings were hinged was in the same location on the fuselage for all configurations so that the position of the wings relative to the fuselage was different for each configuration. The three wing configurations resulted in different center-of-gravity positions for the model with the wings fixed. These center-of-gravity locations were 2.3, 15.3, and 46.6 percent of the mean aerodynamic chord aft of the hinge line for configurations 1, 2, and 3, respectively. Ball bearings were used to minimize the friction in the hinges. The model was tested in most of the configurations with the wing panels hinged to move independently, hinged to move together, and fixed rigidly to the fuselage. In all the test configurations the geometric dihedral of the wing was zero. The model was generally tested without mass balance of the wings, but in configurations 1(a) and 3 with the wings hinged to move independently tests were also made with complete mass balance on the wings. For all of the tests

the towline attachment point was 7 inches above the center line of the fuselage as shown in figure 1.

The tests were conducted in the Langley free-flight tunnel, a complete description of which is given in reference 1. In all the tests the model was towed from the screen at the front of the tunnel test section by means of a light cord, the length of which was about 4 spans during most of the flights. The results presented in reference 2 show that the stability of a towed airplane is increased by increasing the length of the towline and, therefore, the results obtained for these tests are probably conservative because a full-scale target would generally be towed on a towline much longer than that used in the present tests. The tests were made at speeds up to 50 miles per hour, which corresponds to 165 miles per hour for a target of 25-foot wing span based on an approximate scale of 1/10.

It was impossible to disturb the model intentionally because it had no controls, but the irregularities present in the air stream supplied large enough disturbances to reveal instability or light damping.

## RESULTS AND DISCUSSION

The principal results of the investigation are given in table II, which lists the configurations tested and gives a brief summary of the flight behavior for each configuration. Table II is organized so that it shows the effect of the degree of wing freedom on the lateral stability of the model when read across the columns. The effect of the aerodynamic and mass parameters of the wing on the stability of the wings about the hinge is given by comparison of the results within the individual columns.

### Wing Panels Fixed Rigidly to the Fuselage

The data of table II show that satisfactory stability could be obtained with the wing fixed rigidly to the fuselage for both the straight and swept wings for speeds up to 50 miles per hour. This speed was the highest available for the tests and corresponds to a full-scale speed of about 165 miles per hour. The fact that the model was stable with the wings fixed rigidly to the fuselage should be expected since stability can be obtained with a towed glider. (See reference 2.) The flight behavior for configurations 2(b) and 3 was steady through the entire speed range. For these conditions the model did not deviate from its trimmed position unless it was disturbed, and after disturbances it returned with almost deadbeat damping. The flight behavior for condition 1(b) was steady at low speeds but became more sensitive to

disturbances as the speed was increased, until at speeds above 40 miles per hour a large constant-amplitude lateral oscillation resulted. The fact that the behavior of the model was unsatisfactory for configuration 1(b) but was satisfactory for configurations 2(b) and 3 at the same speed may result partly from the fact that the static restoring moments (about the center of gravity of the model) which were produced by the towline were smaller for this configuration than for configurations 2 and 3. The towline moments of configuration 1(b) were smaller because the center of gravity was farther forward for configuration 1(b); the moment arm from the towline attachment point to the center of gravity was 6 percent and 21 percent shorter than for configurations 2(b) and 3, respectively. The tail lengths were also correspondingly shorter in configurations 2(b) and 3 because of the more rearward center-of-gravity locations. The results of reference 2 indicate that, although both increases in the towline moment arm and decreases in tail length would increase the damping of the long-period lateral motions, the magnitude of the changes was too small to explain entirely the difference in behavior between configuration 1(b) and configurations 2(b) and 3. The angle of attack and towline angle (angle between the towline and the longitudinal stability axis) were not measured, and small differences in these angles between the various configurations would have resulted in changes in the magnitude of the towline derivatives. These changes could also have contributed to the differences in behavior between condition 1(b) and conditions 2(b) and 3.

#### Wing Panels Hinged to Move Together

With the wing panels hinged to move together the flight behavior of the model in configuration 1(b) was slightly less satisfactory than with the wing fixed to the fuselage. The lateral oscillation obtained at speeds above 30 miles per hour for configuration 1(b) appeared similar to the conventional Dutch roll oscillation. It involved appreciable sidewise motion in addition to the rolling and yawing, and the frequency of the oscillation was low compared with that obtained when the wing panels were hinged independently.

The fact that the lateral stability of the model with the wings hinged to float together was generally similar to that for the fixed-wing configuration should be expected because the magnitude of all the stability derivatives was about the same for the two wing configurations. In particular, the magnitude of the derivative  $C_{l_p}$ , which represents the main contribution of the wing to lateral stability, was unaffected by the additional degree of freedom. Although the values of the other wing derivatives were reduced to about zero by freeing the wings to float together, the change in the magnitude of these derivatives was small since their values had been small for the fixed-wing configurations. The contributions of the other airplane components (tail and body) to

the stability derivatives were, of course, unchanged. Because no new lateral-stability mode was introduced by the additional degree of freedom, the difference in the lateral stability for configuration 1(b) with the wing fixed and with the wing panels free to float together must have resulted from the small changes in the lateral stability derivatives, resulting from the changes in the wing contributions, and possibly from changes in the towline derivatives, resulting from changes in towline angle and angle of attack. The effect of these small changes in the stability derivatives was not evident for configurations 2(b) and 3 since the model was stable over the entire test-speed range for both fixed-wing and free-wing configurations.

The unstable longitudinal oscillation obtained for configuration 2(a) was a very-high-frequency motion which appeared to consist of pitching of the wings and vertical motion of the entire model. No such oscillation existed for configuration 2(b) which differed from configuration 2(a) by the addition of the tabs. The difference in the stability between configurations 2(a) and 2(b) was probably caused by the changes in the aerodynamic restoring moment and the aerodynamic damping of the wing about the hinge line.

#### Wing Panels Hinged Independently

With the wing panels hinged to move independently of each other, unstable lateral oscillations were obtained for most of the configurations tested. (See table II.) These oscillations consisted principally of rolling and yawing of the complete model and differential movement of the wing panels so that the motion appeared similar to an aileron-free lateral oscillation. The reduction in stability of the model for this degree of wing freedom should be expected because the main contribution of the wing to lateral stability ( $C_{lp}$ ) was eliminated for both the unswept-wing and sweptback-wing configurations. The other derivatives were, as in the case of the wing panels hinged to float together, changed only slightly from the fixed-wing values.

When the hinge was moved forward relative to the wing, as was the case in a change from configuration 1(a) to 2(a) or from configuration 1(b) to 2(b), the stability of the wing oscillation was improved as indicated by the increasing airspeeds at which the lateral oscillations became evident. The stability for configuration 2(b) was satisfactory up to the highest test airspeed (50 mph). This improvement in stability may have been caused by the increase in the magnitudes of the aerodynamic damping moment and the aerodynamic static restoring moment resulting from moving the hinge line forward with respect to the wing.

When the aerodynamic unbalance was increased by sweeping the wing (configurations 1(a) and 3), the stability of the lateral oscillations was not improved. The reason that increasing the aerodynamic unbalance was ineffective in this case probably was that, because of the relatively low lift-curve slope of the swept wing, the aerodynamic damping moment and aerodynamic static restoring moment of the wing were not increased in as great proportion as the moment of inertia of the wing. Because of this characteristic the stability of the swept wing about the hinge line (configuration 3) was less than that of the original unswept wing (configuration 1(a)), and the natural frequency about the hinge line for the swept wing was lower than that for configuration 2(a).

The tests of configurations 1 and 3 with the wings mass-balanced about the hinge line showed that mass balance did not appreciably affect the stability of the lateral oscillation when the wings were hinged independently.

#### CONCLUDING REMARKS

The results of the experimental investigation showed that it was possible to obtain satisfactory stability with the wing panels hinged to float either independently or together at speeds up to the maximum available for the tests, which represented a full-scale speed of about 165 miles per hour. This result does not insure that satisfactory stability can be obtained at greater speeds; in fact, the test results indicate that stability will probably be difficult to obtain at high speed with the wing panels hinged either independently or together.

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#### REFERENCES

1. Shortal, Joseph A., and Osterhout, Clayton J.: Preliminary Stability and Control Tests in the NACA Free-Flight Wind Tunnel and Correlation with Full-Scale Flight Tests. NACA TN 810, 1941.
2. Maggin, Bernard, and Shanks, Robert E.: Experimental Determination of the Lateral Stability of a Glider Towed by a Single Towline and Correlation with an Approximate Theory. NACA RM L8H23, 1948.






TABLE I  
PHYSICAL CHARACTERISTICS OF THE FLIGHT TEST MODELS

Characteristics	Wing sweep (deg)	
	0	45
Weight, lb (approx.) . . . . .	0.242	0.276
Wing:		
Area, sq ft . . . . .	.96	1.12
Span, ft . . . . .	2.4	2.33
Aspect ratio . . . . .	6.0	4.85
Airfoil section perpendicular to leading edge . . . . .	NACA 0012	NACA 0012
Tail surfaces (vertical and horizontal):		
Area, sq ft . . . . .	.099	.099
Aspect ratio . . . . .	2.96	2.96



TABLE II  
SUMMARY OF TEST RESULTS

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Configuration		Flight behavior		
		Degree of freedom of wing panels		
		Fixed rigidly to fuselage	Hinged together	Hinged independently
1(a)		Not tested	Not tested	Unstable lateral oscillation at speeds above 15 mph (relatively short-period motion involving appreciable rolling and differential movement of the wings)
1(b)		Unstable lateral oscillation at speeds above 40 mph (relatively long-period Dutch roll type motion)	Unstable lateral oscillation at speeds above 30 mph (relatively long-period Dutch roll type motion)	Unstable lateral oscillation at speeds above 20 mph (relatively short-period motion involving appreciable rolling and differential movement of the wings)
2(a)		Not tested	Unstable longitudinal oscillation at speeds above 45 mph (short-period pitching of wings coupled with vertical motion of the entire model)	Unstable lateral oscillation at speeds above 40 mph (relatively short-period motion involving appreciable rolling and differential movement of the wings)
2(b)		Steady flight at speeds up to 50 mph.	Steady flight at speeds up to 50 mph	Steady flight at speeds up to 50 mph
3		Steady flight at speeds up to 50 mph	Steady flight at speeds up to 50 mph	Unstable lateral oscillation at speeds above 10 mph (relatively short-period motion involving appreciable rolling and differential movement of the wings)



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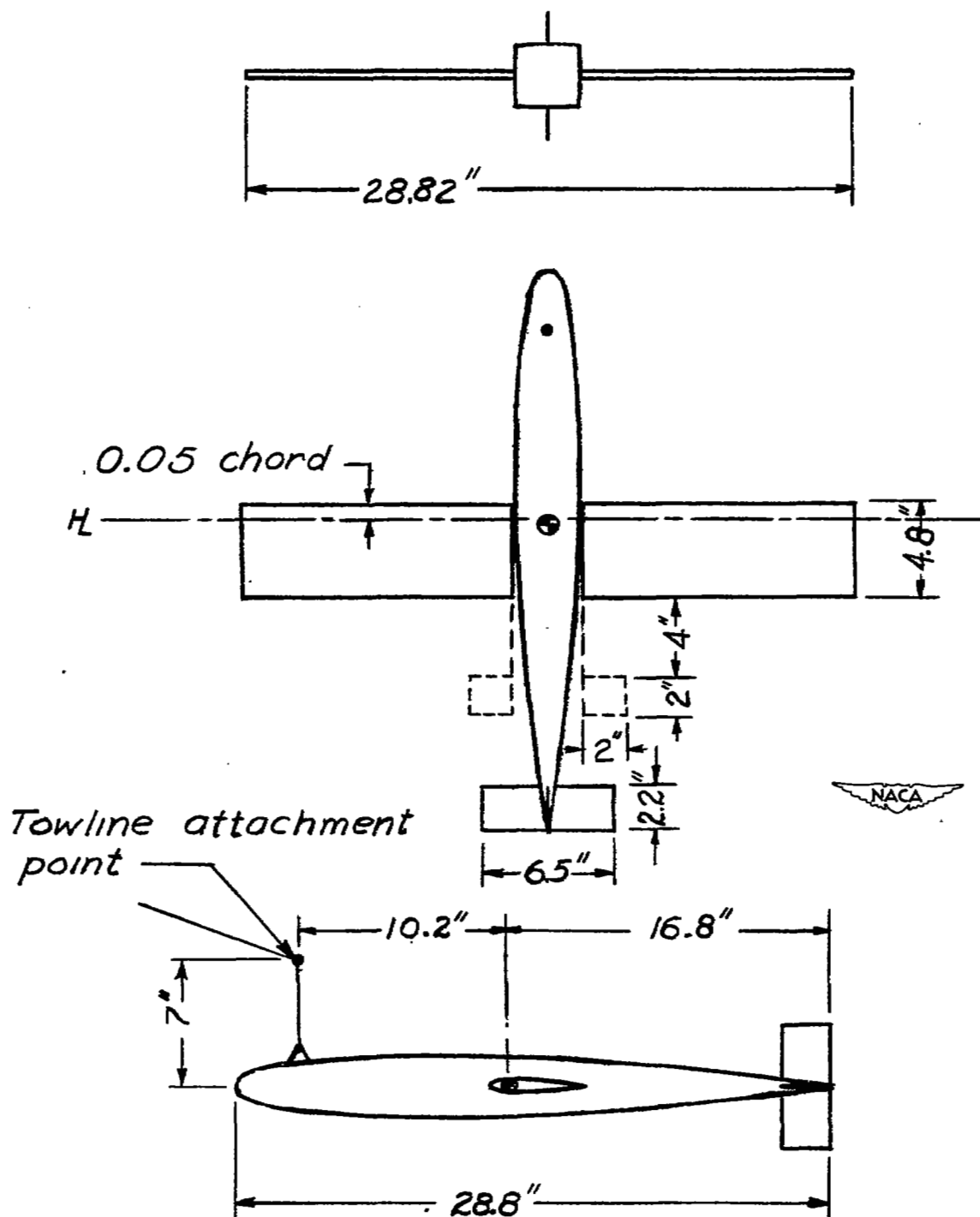


Figure 1.- Three-view sketch of the model in configuration 1.

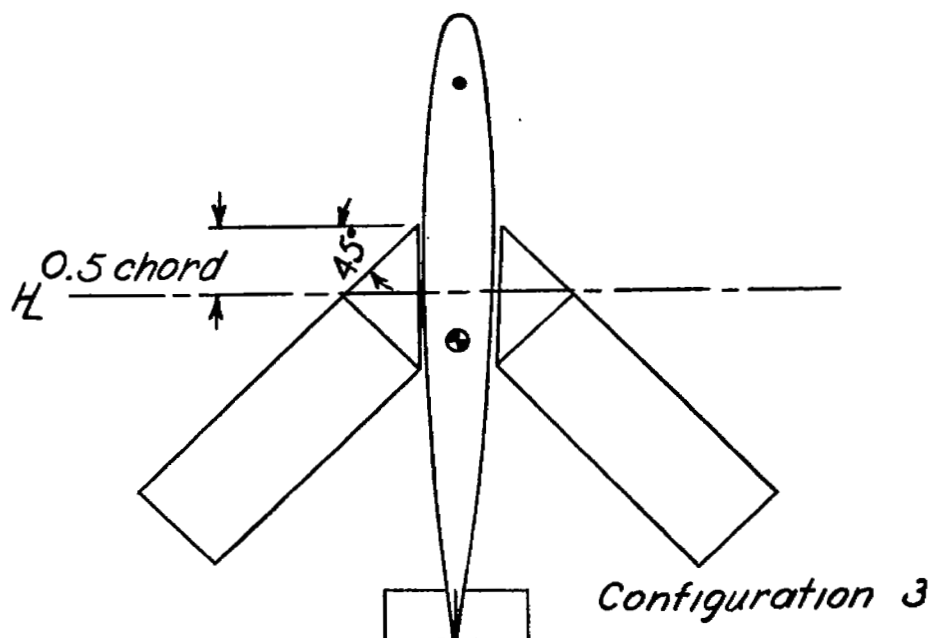
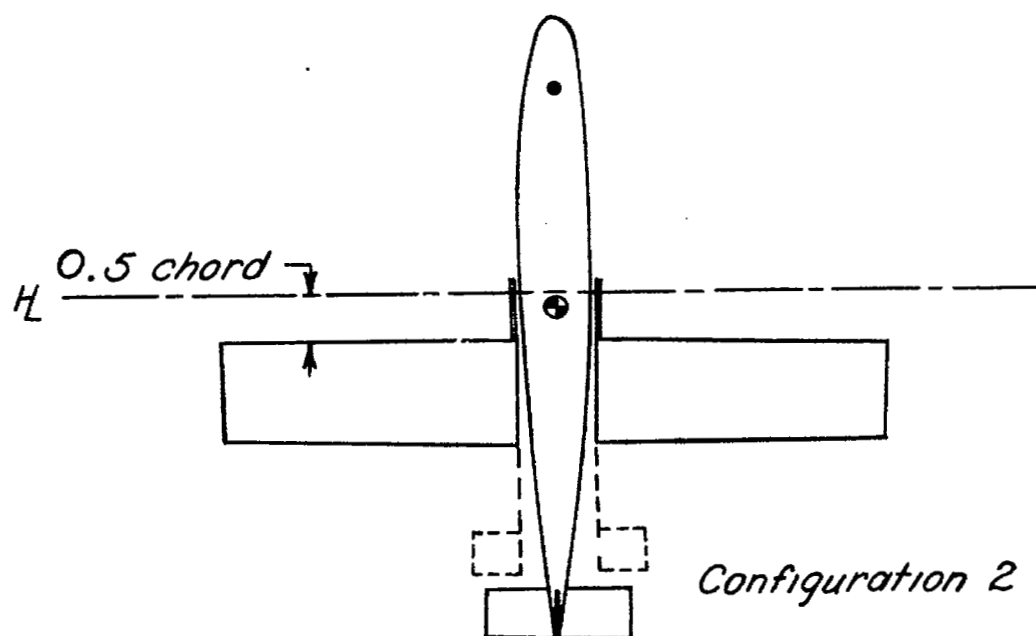


Figure 2.- Plan-view sketches of the model in configurations 2 and 3.

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